# Earthquakes

## **Chapter 3**

# **Earthquakes**

## **What we need to know about the hazards of Earthquakes**

### Understand how scientists measure and compare earthquakes

### The processes behind earthquakes, i.e. faulting, tectonic creep, and the formation of seismic waves

### Which global regions are most at risk for earthquakes and why

### Understands the effects of earthquakes, such as shaking

### Learn the other hazards linked with earthquakes

### Understand the important natural service of earthquakes

### Understand how human beings interact with and affect the earthquake hazard

### Understand how we can minimize seismic risk and what can be done to protect ourselves

# **Earthquake Catastrophes Lessons Learned**

## Earthquakes are devastating events

### These earthquakes can be **catastrophic** when the population is huge or when structures are not built to withstand an earthquake

## Earthquakes may **develop from the movement of magma or sudden ground subsidence**.

## **Fault movement allows an abrupt release of energy, usually after a long, slow accumulation of strain**

## **Fault rupture can take place at the surface and displacement can take place at considerable depth**

# **Earthquakes**

## A **vibration in the Earth produced by shock waves resulting from a sudden displacement along a fault**

## Earthquakes may also **develop from the movement of magma or sudden ground subsidence**.

## **Fault movement allows an abrupt release of energy, usually after a long, slow accumulation of strain**

## **Fault rupture can take place at the surface and displacement can take place at considerable depth**

# **Earthquakes**

## **Building Regulations and zoning can play an important role in determining the extent of damage from earthquakes**

### How deep the was the rupture

### The nature of the soil and rock

### Construction regulations of earthquake regulations effect the number of people and damaged buildings

### We can’t control the geologic environment of depth of an earthquake but we can control sound planning techniques and earthquake engineering of buildings

# **Introduction to Earthquakes**

## **Earthquakes are compared by the amount of energy released**

## **Magnitude** – the relative amount of energy released during an earthquake

## **Shaking Intensity**– intensity scale devised by Giuseppe Mercalli in 1902

### Updated to the **Modified Mercalli intensity scale**

## **The area where the earthquake starts is called the Epicenter**

### This is where the ruptured rocks broke to produce the earthquake

# **Earthquake Basic Features**

## **Epicenter** - Point on surface above surface

## **Surface rupture** – Forms fault scarp amount of slip on fault

## **Focus** – Where rupture on fault plane started

## **Fault Slip** – Direction of the fault slip

## **Fault plane** – Plane of the earthquake

## **Spreading Area** – Area of rupture on the fault plane

## **Surface of the Earth** – Basic surface of the Earth

# **Earthquakes**

# Earthquake Magnitude and Intensity

### **Magnitude** - is determined from an estimate of the area that ruptured along a fault plane during the quake

### Calculated on a logarithmic scale

### Each difference in scale 32 times more intense than the previous.

#### 32 times more energy is released

### Magnitude scale developed by Charles Richter

### Recently “**Moment Magnitude** ” has been developed to be used more by seismologists

### Used more to describe the very large earthquakes- **Earthquake Intensity**

### Estimates the area of rupture along the fault plane during a quake, the amount of movement or slippage along the fault, and the rigidity of the rocks near the focus of the quake

### **Used to prepare online *Community Internet Intensity Maps***

# Earthquake Processes

## **Process of Faulting**

## What are the kinds of faults

### Strike Slip – Transform -a block of crust moves mainly in a horizontal direction

### Dip-Slip – A block of the crust moves mainly in a vertical direction

#### Normal Fault – Hanging wall moves up relative to the foot wall

#### Reverse Fault – Hanging wall moves down relative to the foot wall

#### Overthrust Fault – Hanging wall moves over the foot wall at an angle

## **Fault Activity**

### Active- if movement during the last 200 – 10,000 years

### Potentially Active- if movement during the 10,000 – 1,650,000 Years

### Inactive – if movement during 65,000,000 to 4.6 billion years ago – the age of the earth

# **Types of Faults**

# **Faulting**

## **Faulting results when rock is broken under stress and displacement happens**

### **Fault zones**—a area of weakness in the crust

### **Fault line** – the intersection a fault zone with the Earth’s surface

### **Fault scarps**– steep cliffs that represent the edge of a vertically displaced block

# **Tectonic Creep and Slow Earthquakes**

## **Tectonic Creep** – the gradual movement along a fault which can’t be felt

### These are called **slow earthquakes or fault creep**

### Slowly causes damage to anything built over the land

#### Example: Suncrest housing development built on old slide or creep

#### Roads are cracking and sliding down the mountain

### Newly recognized using GPS devices used to capture geodetic movement

# **Seismic Waves**

## **Start at the Focus – or the epicenter of the earthquake.** (Waves move out from the epicenter like waves in water when rock thrown in)

### **P Waves** – Compressional waves which move through the Earth like sound waves alternately compressing and relaxing the medium that they pass through (like a slinky). Move through both solids and liquids

### **S Waves**– Shear waves which move strong side-to-side, up and down slowing moving waves. Only move through solids.

### **Both P waves and S waves** are “body waves”

### **Surface waves** immediately after the P and S waves arrive on the surface and produce strong side-to-side movement as well as the up-and-down “rolling” motion.

#### One type of surface wave is called a *Love Wave* which especially damages foundations

# **Earthquake Shaking**

## Three important factors determine the shaking you will experience during an earthquake

### **Earthquake magnitude**

### **Your location in relation to the epicenter and direction of rupture**

### **Local Soil and rock conditions**

## **Generally strong shaking may be expected from earthquakes of moderate magnitude (M 5 – 5.9) or larger**

## **These types of earthquakes will cause the ground to rock and roll damaging building and other structures**

## **DUH!!!!!**

# **Earthquake Shaking**

## **Distance from the Epicenter**

### Using Seismographs which produce a seismogram, the epicenter can be located by looking at the travel speed of the P and S waves

### Scientists use triangulation from more than 4 seismic centers to locate the Epicenter

## **Depth of Focus**

### The depth of the earthquake **focus** determines how much “shaking” well happen

### The deeper the focus the less shaking is felt on the surface

### Seismic waves lose much of their energy (*attenuation*) if the focus is deep in the earth

## **Direction of Rupture**

### Although the rupture from the focus may move in many directions the path of the greatest rupture can focus the earthquake energy. This is the **directivity**.

#### Contributes to the *amplification of seismic waves and shaking*

# **Seismograph**

# **Earthquake Shaking**

## **Supershear**

### Occurs when the **propagation of rupture** is **faster** than the velocity of shear-waves or surface waves produced by the rupture

### Supershear con produce **shock waves that produce strong ground motion** along the fault

# **Earthquake Shaking**

## **Local Geologic Conditions**

### The **nature of the local earth materials and geologic structure strongly influences** the amount of ground motion

### Earth materials **behave differently in an earthquake**

### If the earth material causes the **P and S waves to slow down** the forward **energy is focused vertically**; this is known as **material amplification**

### This movement strongly **influences the ground motion** of an earthquake

### **Local geologic structures** can also influence the amount of shaking

#### Synclines and fault-bounded sedimentary basins can focus seismic waves the way a magnifying lens focuses sunlight

#### This causes severe shaking in some areas and less intense shaking in others

# **The Earthquake Cycle**

## From the 1906 San Francisco earthquake observations were made that led to a hypothesis know as the **earthquake cycle**

## The **earthquake cycle proposes that there is a drop in elastic strain after an earthquake and a reaccumulation of strain before the next event**

## **Strain is deformation resulting from stress**

## **Elastic strain** may be thought of as **deformation that is not permanent, provided the stress is eventually released**

## When the **stress is released, the elastically deformed material returns to is original shape**

## This **release of pent-up energy is what happens when an earthquake happens, sometimes deformity is left after the quake**

# **Geographic Regions at Risk from Earthquakes**

## Earthquakes are not randomly distributed

## There are well-defined zones along the boundaries of Earth’s tectonic plates

## **Plate Boundary Earthquakes**

### Earthquakes occur along all three types of plate boundaries

#### Convergent

#### Divergent

#### Transform

### The world’s greatest earthquakes that happen in the last 100 years have been along **megathrust subduction zones**

#### These are called **megathrust earthquakes**

### In the western United States, **earthquakes are common along the transform San Andreas fault zone and the convergent Cascadia and Aleutian subduction zones**

### The **states along the Rocky Mountains (including Utah) experience many earthquakes**

## **Knowing the probably location, the magnitude and effects of an earthquake allows for plans to be made to decrease loss of life and damage**

## **Intraplate Earthquakes**

### **Less common**

### **Can be large and extremely damaging**

### They don’t happen often so **people are less prepared for them**

#### There were **two large earthquakes 1811-12** during the winter in the central Mississippi Valley

#### Felt all over the eastern states from New Orleans to Boston to Quebec City

#### Produced a intense surface deformation over a wide area of Memphis, Tennessee north to the confluence of the Mississippi and Ohio Rivers

#### These two earthquakes occurred along the New Madrid seismic zone, part of a geologic structure known as the Mississippi Embayment

#### It is figured that earthquakes happen along this embayment at a *recurrence interval*, once every several hundred years

## **Shaking is not the only cause of death and damages during earthquakes**

### **Earthquakes often cause other hazards or linkages to other natural hazards**

## **Shaking and Ground Rupture**

### A major ground rupture from an earthquake causing a short cliff is called a **Fault Scarp**

### This cliff is not an “opening to the inside of the earth” like some movies insinuate

### Buildings can experience damage by violent shaking called ground acceleration

#### This can cause the building to shake by matching is frequency or **resonance**

## **Liquefaction**

### **Shaking of water-saturated material**

### Turns clay soil to fluid resulting in subsidence, fracturing, and horizontal sliding of the ground surface

## **Regional Changes in Land Elevation**

### **Vertical deformation of the land surface** is linked to large earthquakes

### Includes regional uplift and subsidence of the earth’s surface

### Can cause substantial damage to coastal areas and along streams

## **Landslides**

### **Landslides are the closest physical link to earthquakes**

### Earthquakes are the most common trigger of landslides

### Can be extremely damaging and cause a large loss of life

## **Fires**

### **Happens when surface is displaced and electrical power and natural gas pipes break**

### Larger threat when water mains break, roads and bridges broken, blocking fire equipment ability to get to fire and put it out

## Disease

### **Outbreaks of diseases** sometime occur during large earthquakes because of the **loss of sanitation, housing, contamination of water** and other public health problems

## **Finding benefits from earthquakes**

## **Can sound like it would be difficult, but there are some natural service functions from earthquakes**

## **Groundwater and Energy Resources**

### Movements of faults as a result of earthquakes allow the **underground flow of water, oil, and natural gas**

## **Mineral Resources**

### Faulting from earthquakes may be responsible for the **accumulation or exposure of economically valuable minerals**, like **veins of gold, silver or other valuable minerals**

#### **Oquirrh Mountains (many types of minerals**

## **Landform Development**

### Earthquakes can form **scenic landforms** over long intervals of geologic time

#### **Many parts of central and southern Utah**

## **Future Earthquake Hazard Reducti**on

### By having **small earthquakes the tension is released** avoiding that “big one”

## **Earthquakes Caused by Human Activity**

### **Four** ways the actions of people have caused earthquakes

#### Over -Loading the Earth’s crust with building a dam and reservoir

#### Injecting Liquid waste deep water into the ground through disposal wells

#### Creating underground nuclear explosions

#### Hydraulic Fracturing-exploring for oil and natural gas

## **Loading the Earth’s crust as in building a dam and reservoir**

### **Water reservoirs may create or induce earthquakes**

#### The huge weight of the water can create or extend fractures in adjacent rock

#### Increases water pressure in the surrounding groundwater causing earthquakes

## **Injecting liquid waste deep into the ground through disposal wells**

### **Deep Waste Disposal** was an experiment of the US Army in the 1960’s

### **This experiment** provided the direct evidence that injecting fluids into the earth can cause earthquakes

### Increases underground fluid and pressure **which caused slippage of numerous fractures of metamorphic rock**

### **When this was discontinued, the earthquakes quit, an important find**

## **Creating underground nuclear explosions**

### During the **1960’s (again) the testing of nuclear explosions was moved from the surface to underground protecting people living downwind**

### It was thought that these **explosions could be used to release the seismic tension in underground rock**

### It **really doesn’t work**, and there is still the problem of having any nuclear explosions

## **Hydraulic Fracturing (Fracking)**

### The **new way of looking for oil, coal, shale gas, or natural gas**

### Found in Oklahoma, Pennsylvania, Ohio, and many other states

### Started in 1947, lately being used more in the past 10 years

### Besides the **environmental problems that can occur, earthquakes have been tied to fracturing**

### In 2011, **Oklahoma experienced its largest earthquake**. It was thought to be linked to fracturing processes being practiced in the state, but the **USGS declared it was probably natural**

### **Other earthquakes have been felt in areas where fracturing has been used.**

# **Minimizing the Earthquake Hazard**

## **Earthquakes cause lots of damage and loss of life consequently there has been research into how to forecast an earthquake**

## It would be hoped that by forecasting earthquakes lives and damage can be decreased

## So the **National Earthquake Hazard Reduction Program was formed with these goals**

### **Develop and understanding of the earthquake source**

#### Requires obtaining information about the physical properties and mechanical faults and develop models about the process

### **Determine earthquake potential**

#### Study the seismically active regions to determine their paleoseismicity, identify active faults and rates of deformation

### **Predict effects of earthquakes**

#### Obtain information needed to calculate the predict the ground rupture and shaking on buildings

### **Apply research results**

#### The program educates individuals, communalities, states, and the nation about earthquakes

# **Minimizing the Earthquake Hazard**

## **Estimation of Seismic Risk**

### Seismic hazard maps can be used to help formulate where earthquakes can happen

## **Short-term Prediction**

### Active area of research

### Relies on precursors, events or changes that occur prior to main shock

### Doesn’t always work, prediction a complex problem

### If predictions actually are formulated they will be based on

#### Patterns and frequency of

#### Deformation of the ground surface

#### Seismic gaps along faults

#### Geophysical and geochemical changes

# **Minimizing the Earthquake Hazard**

## **The Future of Earthquake Prediction**

### Scientists have been working on prediction but still haven’t got a good system

### Progress has been made on short-term, but long-term forecasting is still along way off

### **Earthquake Warning Systems**

#### It is technical feasible that an earthquake warning system could be made that would give a 1 minute warning

#### But if there were false alarms, people would begin to not take them seriously

### Because there aren’t ways to predict or warn people of earthquakes there are problems with the perception of and adjustment to the earthquake

## **Perception of the Earthquake Hazard**

### Society is vulnerable to catastrophic loss from large earthquakes due to old buildings, too big of buildings and many other problems

# Minimizing the Earthquake Hazard

## **Community Adjustments to the Earthquake Hazard**

### Since we can’t avoid living in earthquake prone areas, society needs to take steps to adjust to the earthquake hazard by doing these following steps to avoid these hazards

### **Location of Critical Facilities**

#### Facilities which are critical to communities need to located in safe areas

### **Structural Protection**

#### The need to build buildings so they don’t fall down and kill people will make society safer if an earthquake should happen

### **Education**

#### Education on what and how to protect yourself during an earthquake and how to build earthquake safe, decreases the hazards of earthquakes

### **Increase Insurance and Relief Measures**

#### If you are in an earthquake prone area, take get earthquake insurance,

### **Personal Adjustments**

#### Make adjustments to your home to make it earthquake safe and have a plan if an earthquake happens